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**Yokogawa**

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(54) **ARMATURE AND MOTOR**


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(51) **Int. Cl.**

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***H02K 3/52*** (2006.01)
*H02K 3/30* (2006.01)
*H02K 3/46* (2006.01)
*H02K 3/32* (2006.01)

(52) **U.S. Cl.**

CPC ................ ***H02K 3/345*** (2013.01); ***H02K 3/522*** (2013.01); *H02K 3/30* (2013.01); *H02K 3/325* (2013.01); *H02K 3/46* (2013.01); *H02K 2203/12* (2013.01)

(58) **Field of Classification Search**

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USPC ................................................. 310/154, 215

See application file for complete search history.


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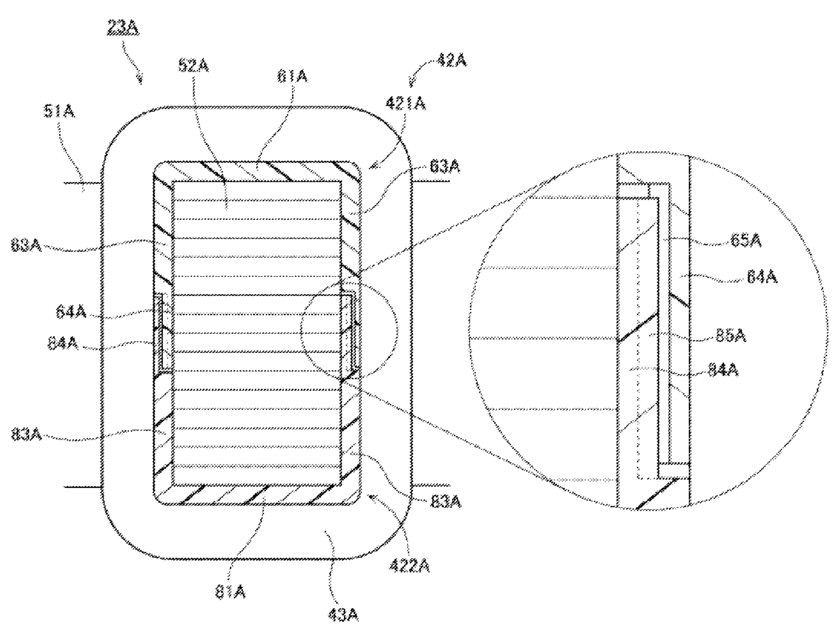
(57) **ABSTRACT**


An insulator of an armature includes an upper resin member and a lower resin member. Each of the upper and lower resin members includes decreased thickness portions. Axial positions of the decreased thickness portions of the upper and lower resin members are arranged to overlap at least partially with each other. Each of the upper and lower resin members further includes a rib arranged to project from a corresponding one of the decreased thickness portions. The rib improves the strength of the corresponding decreased thickness portion and reduces the likelihood that any of the decreased thickness portions of the upper and lower resin members will be damaged when the two members are fitted to each other.


**19 Claims, 10 Drawing Sheets**



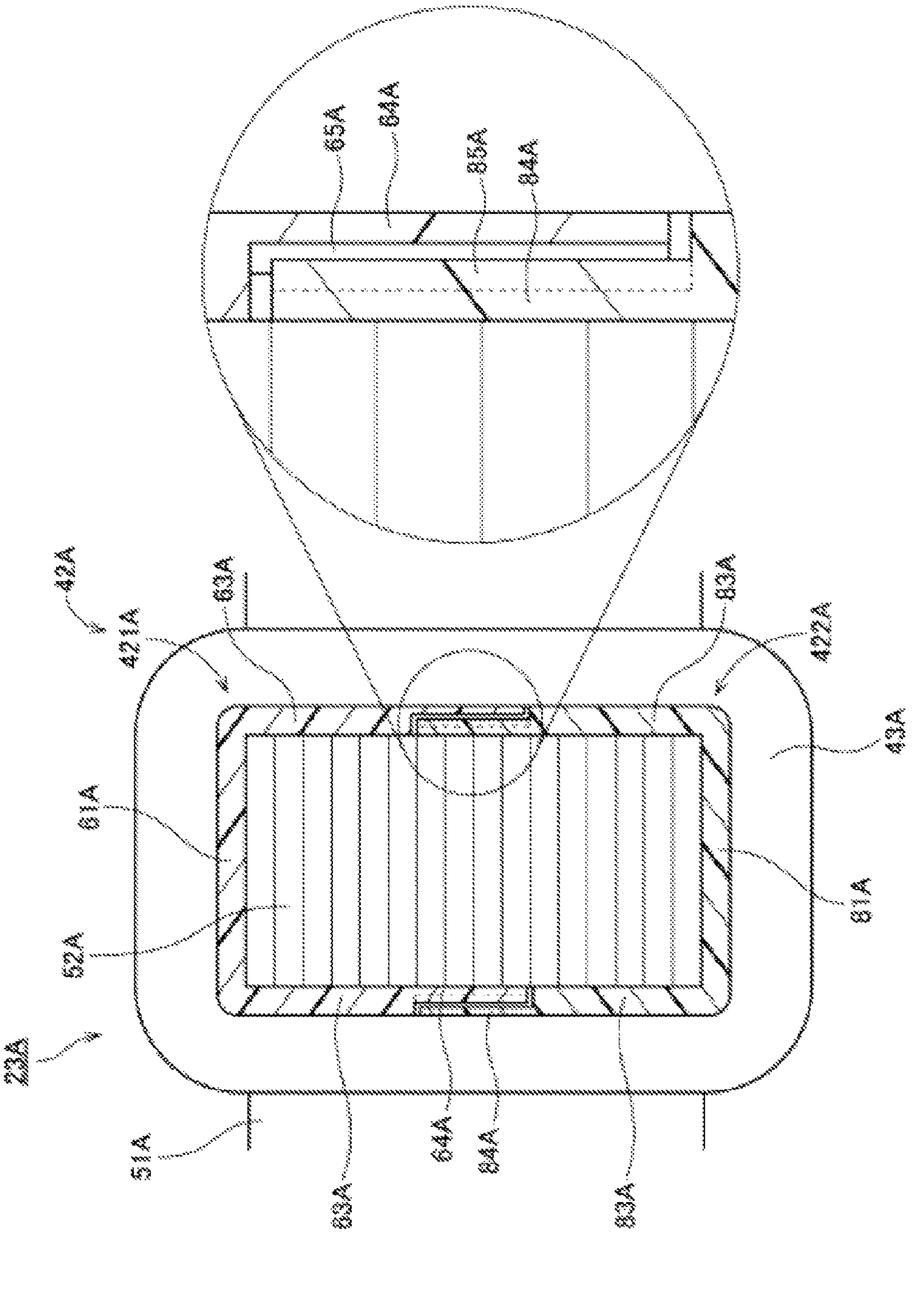

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Fig.1

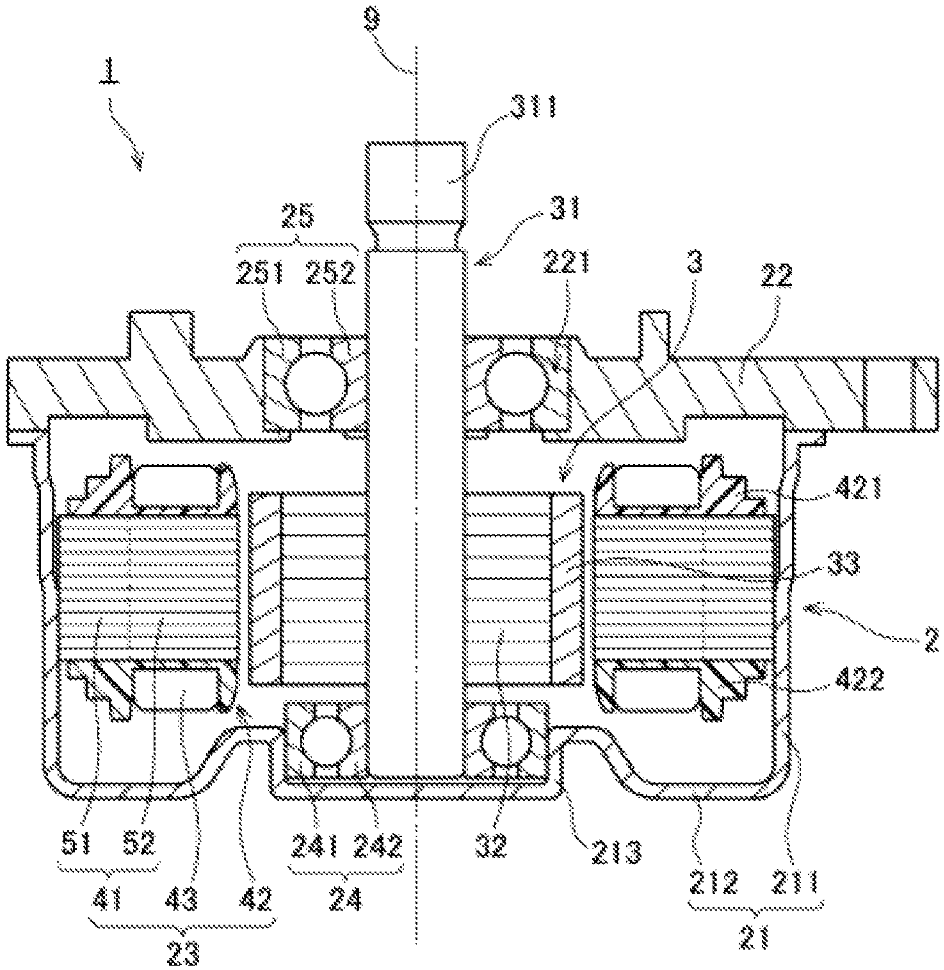
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Fig.2

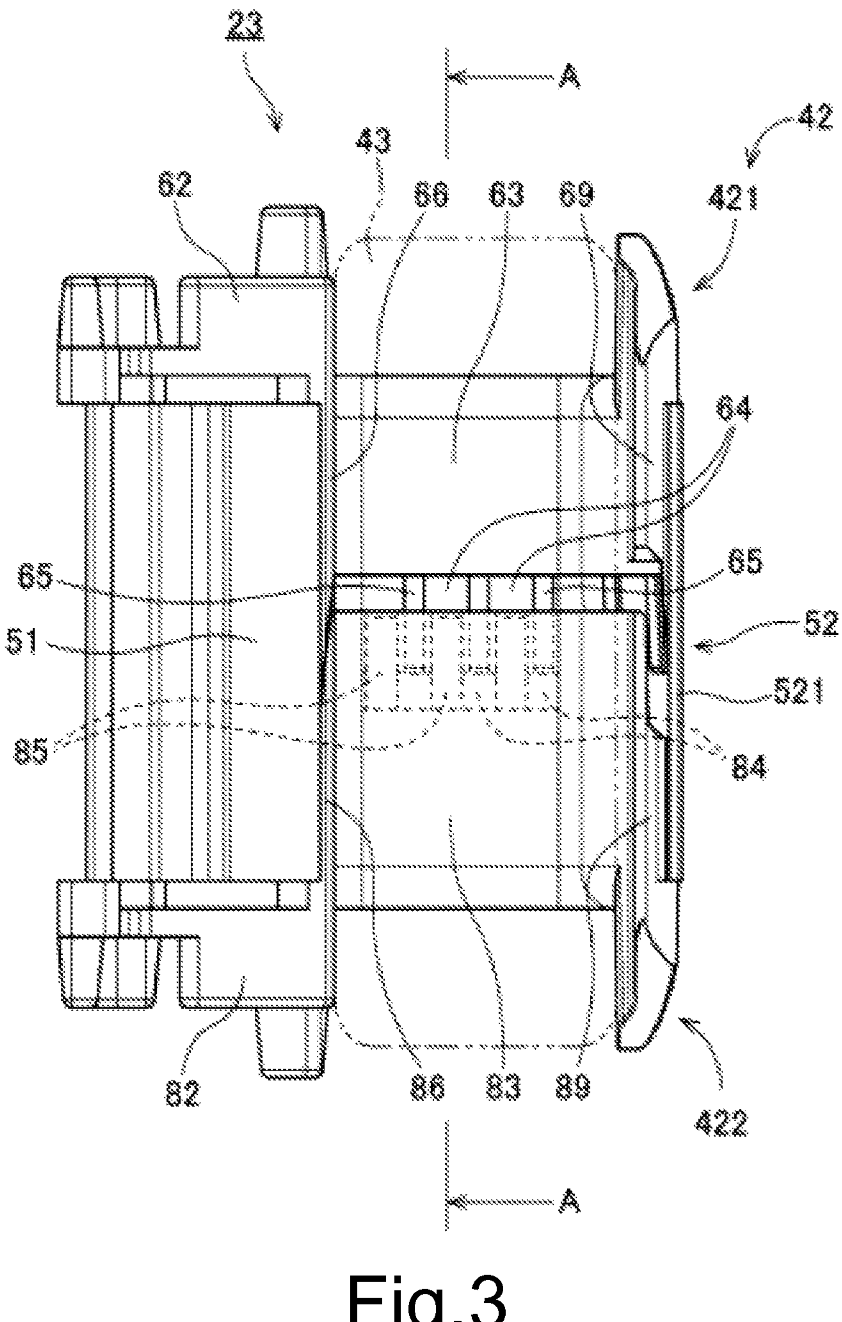


Fig.3

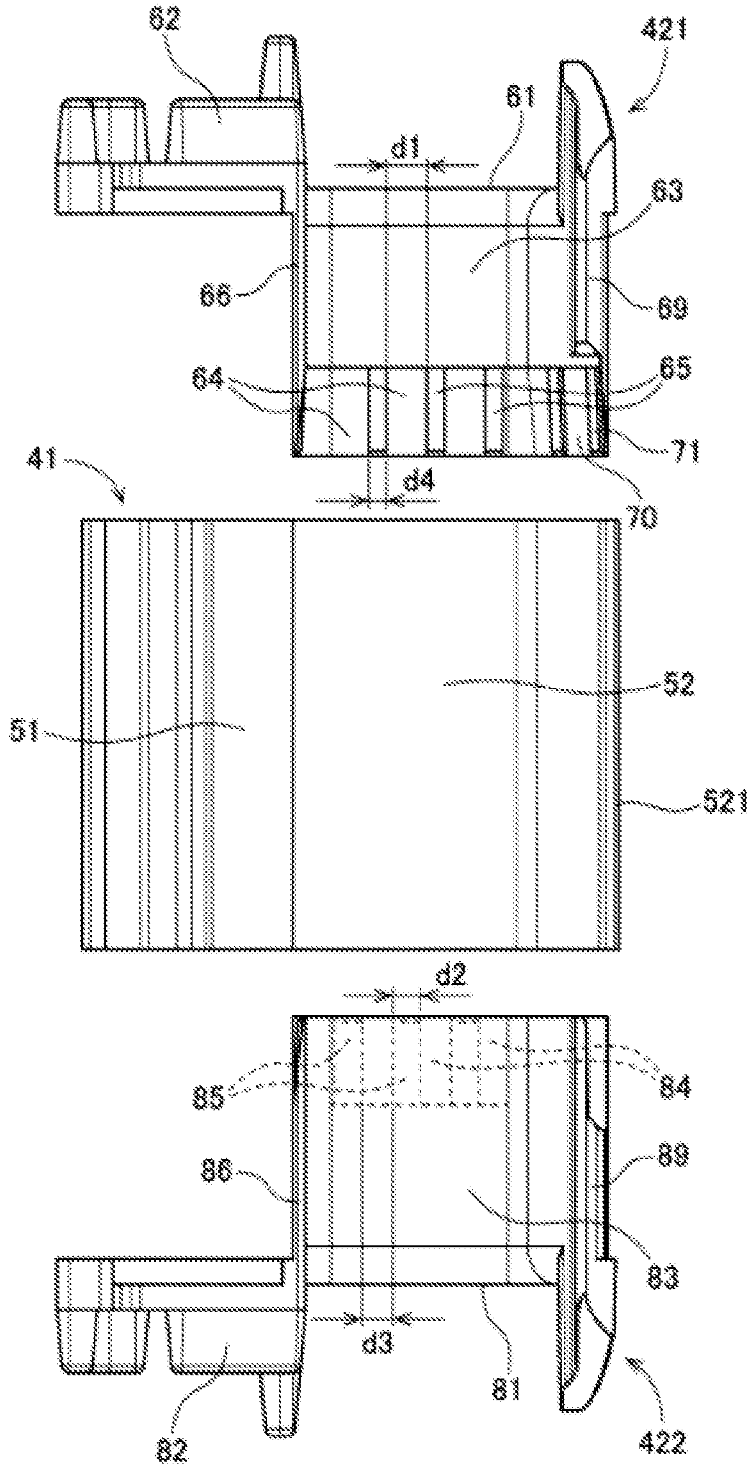
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Fig.4

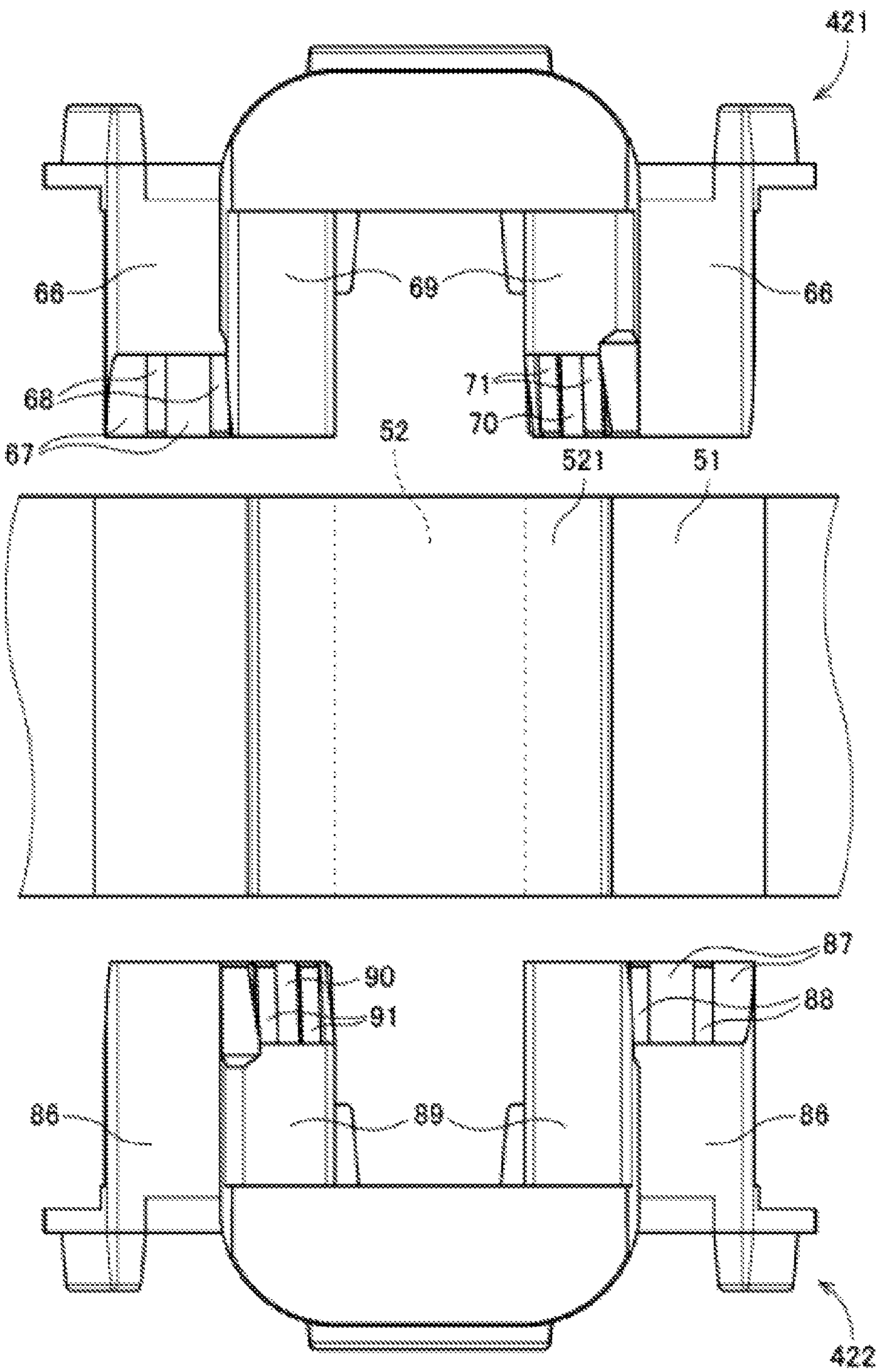


Fig.5

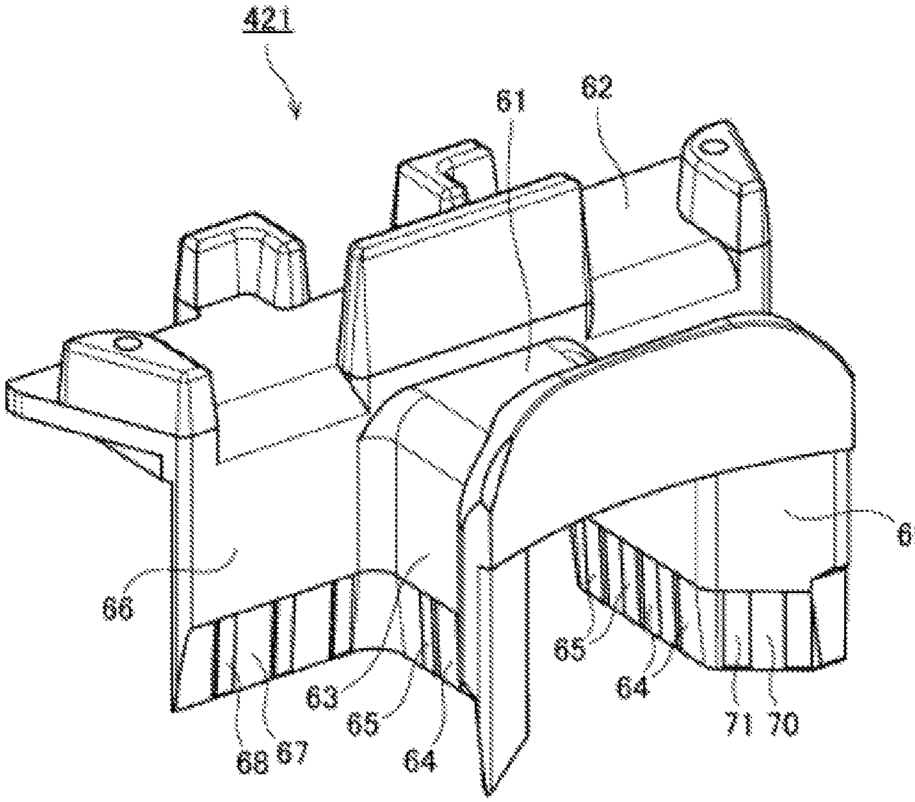


Fig.6

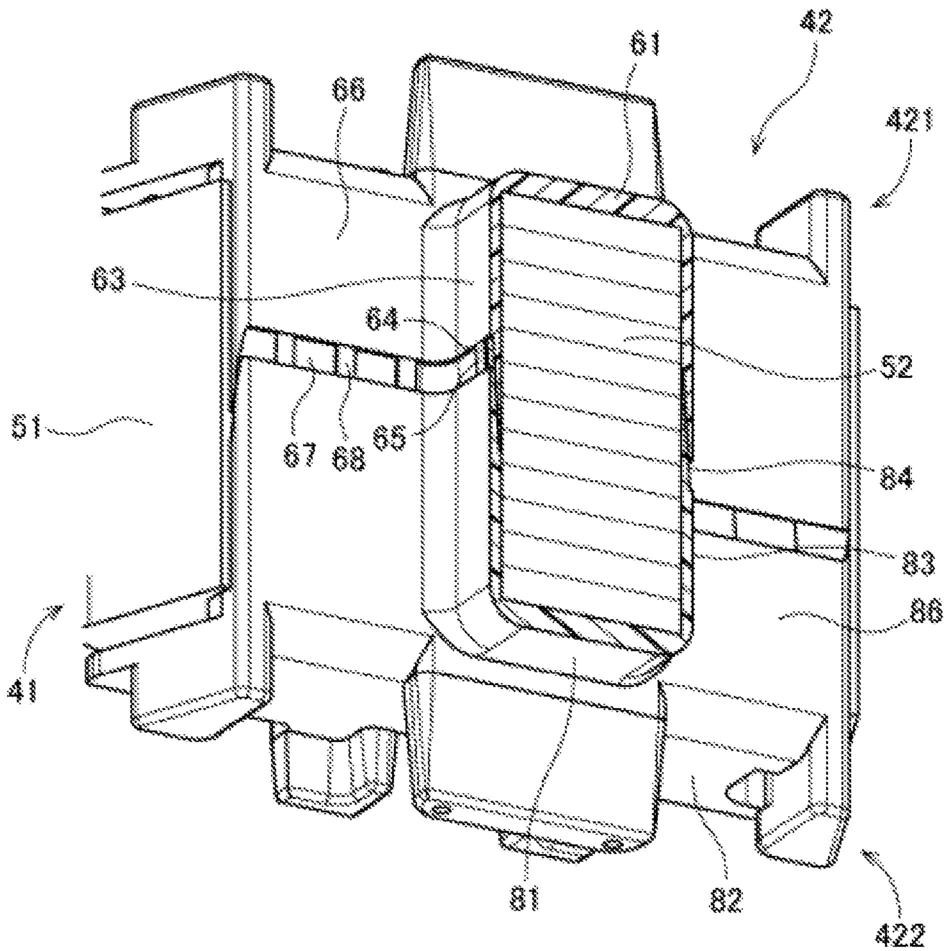


Fig.7

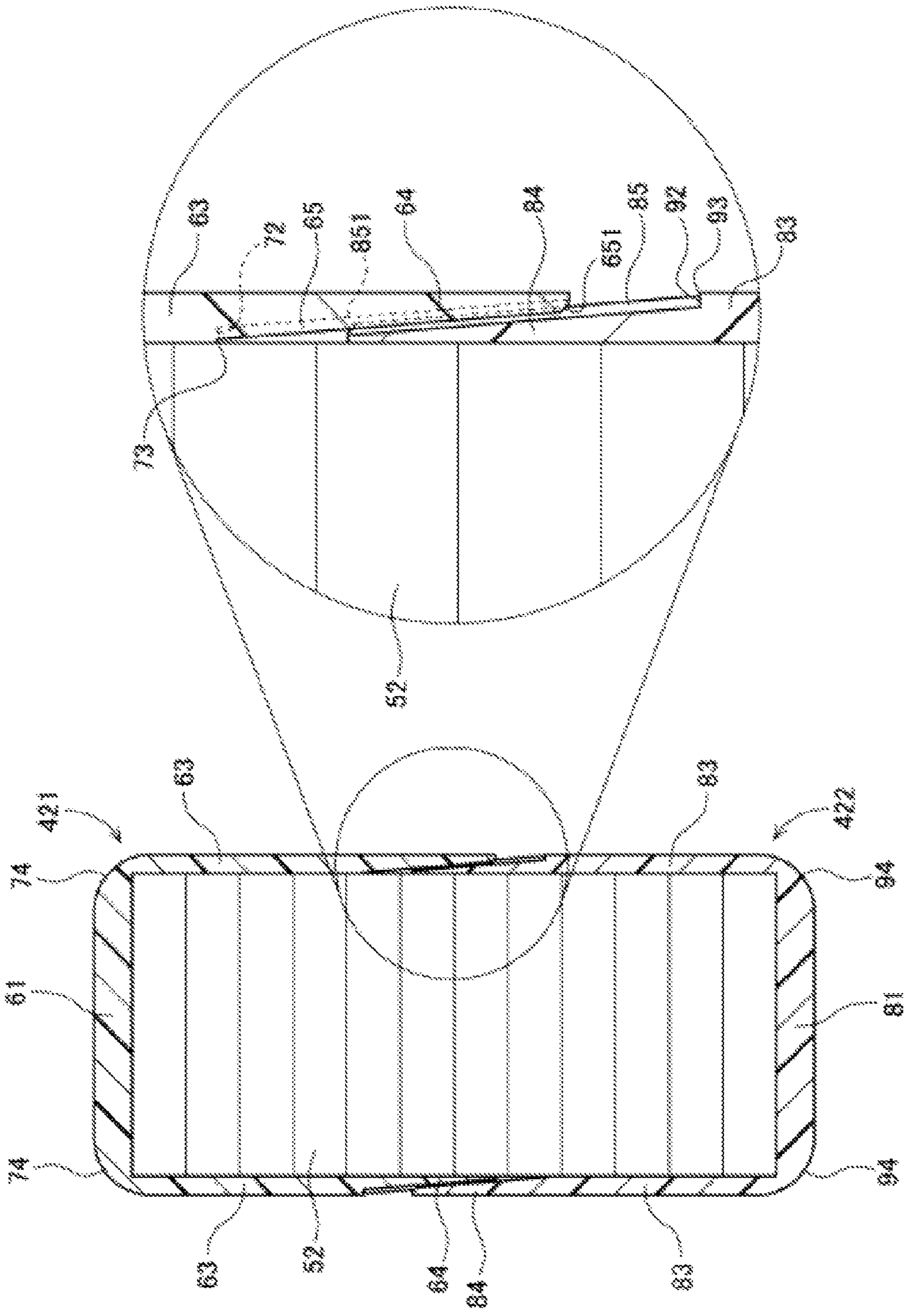
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Fig.8

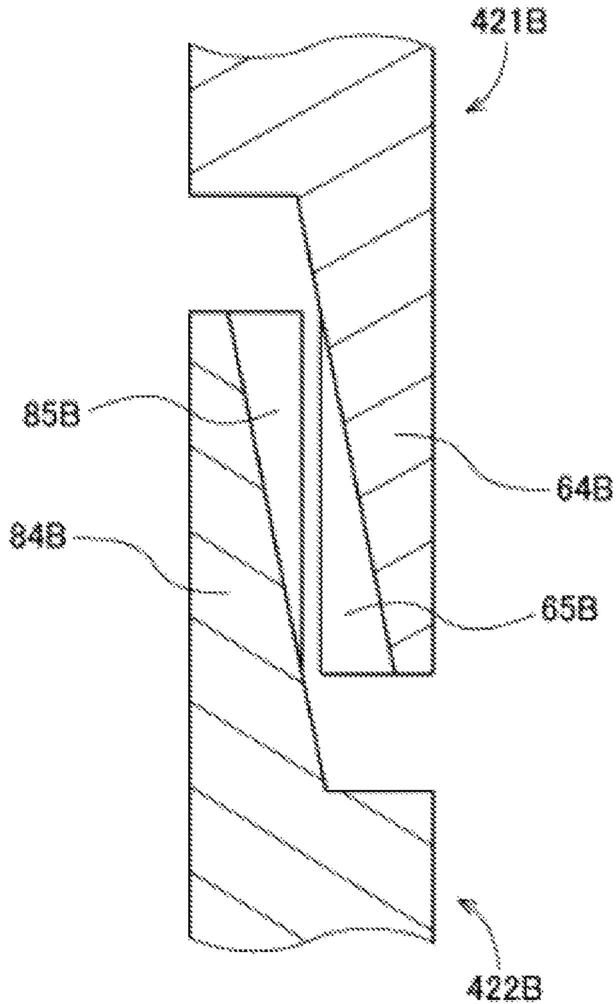


Fig.9

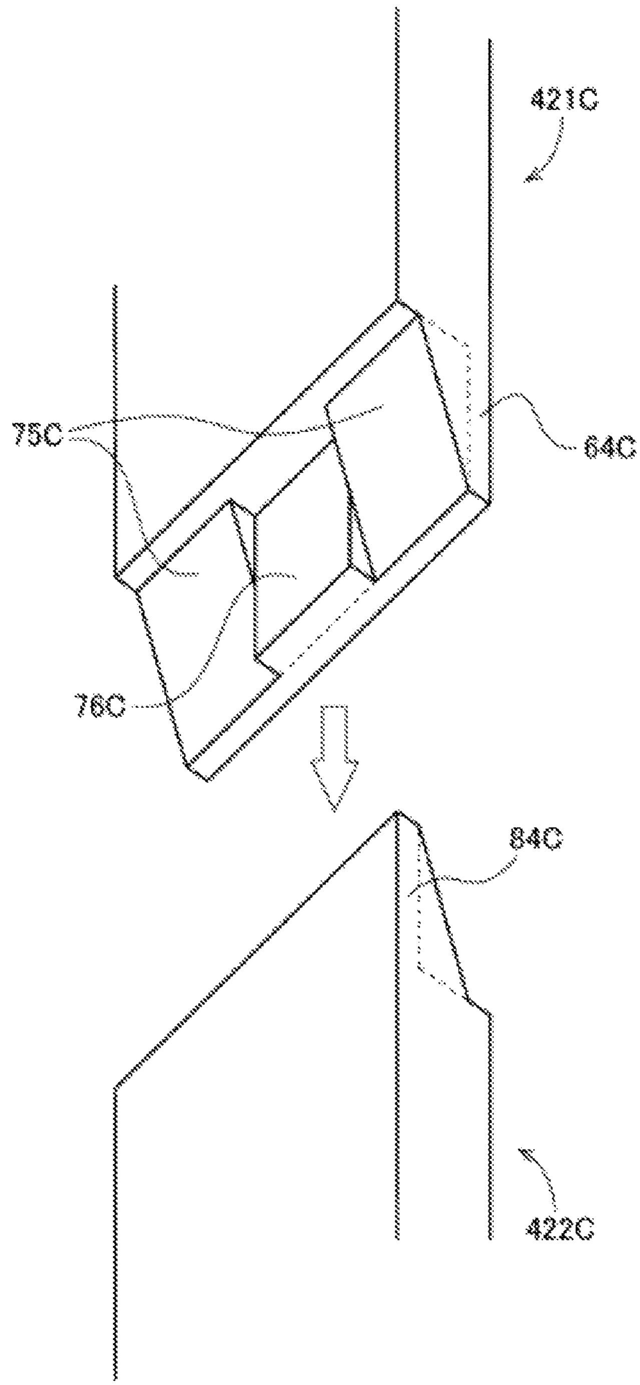


Fig.10

# ARMATURE AND MOTOR

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an armature and more specifically to an armature for use in a motor.

2. Description of the Related Art

JP-A 2003-079080 describes a stator including a stator core, coils, and insulating members, as an example of a conventional armature used in a motor. In the stator described in this publication, each insulating member, which is tubular in shape, is arranged between a separate one of the coils and a corresponding one of magnetic pole teeth of the stator core (see, e.g., claim 1 of JP-A 2003-079080). In addition, each insulating member described in JP-A 2003-079080 is made up of two insulating member pieces joined to each other (see, e.g., claim 3 of JP-A 2003-079080). Moreover, the two insulating member pieces described in JP-A 2003-079080 are fitted to each other such that end portions of the insulating member pieces overlap with each other (see paragraph [0024] and FIG. 3 of JP-A 2003-079080).

In the stator described in JP-A 2003-079080, however, fitting portions of the two insulating member pieces together define an increased thickness portion of the insulating member (see paragraph [0024] and FIG. 3 of JP-A 2003-079080). The increased thickness portion is the thickest portion of the insulating member. According to the above structure, a space in which the coil is to be arranged is narrowed by each increased thickness portion of the insulating member. In order to increase the number of turns of each coil while preventing an excessive increase in the size of the motor, it is desirable to minimize an increase in the thickness of a portion of the insulating member where the two insulating member pieces overlap with each other.

However, simply reducing the thickness of each end portion of each insulating member piece would result in difficulty in ensuring a sufficient strength of each end portion of each insulating member piece. A decrease in the strength of each end portion of each insulating member piece might permit any of the insulating member pieces to be damaged by, for example, contact between the end portions of the insulating member pieces when the two insulating member pieces are fitted to each other. Moreover, a decrease in the thickness of each end portion of each insulating member piece would narrow a channel through which a molten resin flows in a resin molding process. This might lead to a decreased precision in molding.

## SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a structure of an insulator including a pair of resin members fitted to each other that prevents both damage of each resin member and a decreased precision in molding of each resin member.

According to a preferred embodiment of the present invention, an armature includes an annular core back; a plurality of teeth arranged to extend radially inward or radially outward from the core back; insulators each of which is arranged to cover a separate one of the teeth; and coils, each of which is defined by a conducting wire wound around a separate one of the insulators. Each insulator includes an upper resin member and a lower resin member. The upper resin member includes a top plate portion arranged to cover an upper surface of a corresponding one of the teeth; a pair of upper side wall portions each of which is arranged to extend downward from a separate circumferential end portion of the top plate portion to cover an upper region of a separate one of circumferential side surfaces of the tooth; a pair of first upper decreased thickness portions each of which is arranged to extend further downward from a lower end portion of a separate one of the upper side wall portions, each first upper decreased thickness portion having a circumferential thickness smaller than that of each upper side wall portion; and a first upper rib. The lower resin member includes a bottom plate portion arranged to cover a lower surface of the tooth; a pair of lower side wall portions, each of which is arranged to extend upward from a separate circumferential end portion of the bottom plate portion to cover a lower region of a separate one of the circumferential side surfaces of the tooth; a pair of first lower decreased thickness portions, each of which is arranged to extend further upward from an upper end portion of a separate one of the lower side wall portions, each first lower decreased thickness portion having a circumferential thickness smaller than that of each lower side wall portion; and a first lower rib. An axial position of each of the first upper decreased thickness portions and the first upper rib is arranged to overlap at least partially with an axial position of each of the first lower decreased thickness portions and the first lower rib. The first upper rib is arranged to project in a circumferential direction from a surface of a corresponding one of the first upper decreased thickness portions toward a corresponding one of the first lower decreased thickness portions. The first lower rib is arranged to project in the circumferential direction from a surface of a corresponding one of the first lower decreased thickness portions toward a corresponding one of the first upper decreased thickness portions. Each of the circumferential thickness of each first upper decreased thickness portion and a combined circumferential thickness of the first upper decreased thickness portion and the first upper rib is arranged to decrease with decreasing height or to be uniform. Each of the circumferential thickness of each first lower decreased thickness portion and a combined circumferential thickness of the first lower decreased thickness portion and the first lower rib is arranged to decrease with increasing height or to be uniform. A radial width of the first upper rib is arranged to decrease with decreasing height or to be uniform. A radial width of the first lower rib is arranged to decrease with increasing height or to be uniform.

According to the above preferred embodiment of the present invention, the strength of the first upper decreased thickness portion is significantly improved by the first upper rib. In addition, the strength of the first lower decreased thickness portion is significantly improved by the first lower rib. This reduces the likelihood that any of the first upper decreased thickness portion and the first lower decreased thickness portion will be damaged when the upper and lower resin members are fitted to each other. Moreover, channels through which a molten resin flows in a molding process are expanded by spaces arranged to permit molding of the ribs. This preferably improves precision with which each of the decreased thickness portions is molded.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of an armature according to a first preferred embodiment of the present invention taken along a plane perpendicular to a direction in which one of teeth extends.

FIG. **2** is a vertical cross-sectional view of a motor according to a second preferred embodiment of the present invention.

FIG. **3** is a side view of a tooth and an insulator according to the second preferred embodiment of the present invention.

FIG. **4** is an exploded view of the tooth, an upper resin member and a lower resin member according to the second preferred embodiment of the present invention.

FIG. **5** is an exploded view of the tooth, the upper resin member, and the lower resin member according to the second preferred embodiment of the present invention.

FIG. **6** is a perspective view of the upper resin member according to the second preferred embodiment of the present invention.

FIG. **7** is a partial perspective view of a stator core and the insulator according to the second preferred embodiment of the present invention.

FIG. **8** is a cross-sectional view of the tooth and the insulator according to the second preferred embodiment of the present invention taken along a plane perpendicular to a direction in which the tooth extends.

FIG. **9** is a partial vertical cross-sectional view of an upper resin member and a lower resin member according to another preferred embodiment of the present invention.

FIG. **10** is a partial exploded perspective view of an upper resin member and a lower resin member according to another preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be described with reference to the accompanying drawings. It is assumed herein that a direction parallel or substantially parallel to a central axis of a motor is referred to by the term "axial direction", "axial", or "axially", that directions perpendicular or substantially perpendicular to the central axis of the motor are referred to by the term "radial direction", "radial", or "radially", and that a direction along a circular arc centered on the central axis of the motor is referred to by the term "circumferential direction", "circumferential", or "circumferentially". It is also assumed herein that a vertical direction is the axial direction, and that a side on which a top plate portion of an insulator is arranged with respect to a bottom plate portion of the insulator is defined as an upper side. The shape of each member or portion and relative positions of different members or portions will be described based on the above assumptions. It should be noted, however, that the above definitions of the various directions are simply made for the sake of convenience in description, and should not be construed to restrict in any way the orientation of an armature or a motor according to any preferred embodiment of the present invention when in use.

First Preferred Embodiment

FIG. **1** is a cross-sectional view of an armature **23**A according to a first preferred embodiment of the present invention taken along a plane perpendicular to a direction in which one of teeth **52**A extends. Referring to FIG. **1**, the armature **23**A preferably includes a core back **51**A, the teeth **52**A, insulators **42**A, and coils **43**A.

The core back **51**A preferably has an annular shape. The teeth **52**A are arranged to extend radially inward from the core back **51**A. Note that the teeth **52**A may alternatively be arranged to extend radially outward from the core back **51**A. An upper surface, a lower surface, and circumferential side surfaces of each of the teeth **52**A are preferably covered by a separate one of the insulators **42**A. Each of the coils **43**A is preferably defined by, for example, a conducting wire wound around a separate one of the insulators **42**A.

Each insulator **42**A preferably includes an upper resin member **421**A and a lower resin member **422**A.

The upper resin member **421**A preferably includes a top plate portion **61**A, a pair of upper side wall portions **63**A, and a pair of first upper decreased thickness portions **64**A. The upper surface of the tooth **52**A is preferably covered by the top plate portion **61**A. Each of the upper side wall portions **63**A is arranged to extend downward from a separate circumferential end portion of the top plate portion **61**A. An upper region of each circumferential side surface of the tooth **52**A is preferably covered by a separate one of the upper side wall portions **63**A. Each of the pair of first upper decreased thickness portions **64**A is arranged to extend further downward from a lower end portion of a separate one of the upper side wall portions **63**A. Each first upper decreased thickness portion **64**A is preferably arranged to have a circumferential thickness smaller than that of each upper side wall portion **63**A.

The lower resin member **422**A preferably includes a bottom plate portion **81**A, a pair of lower side wall portions **83**A, and a pair of first lower decreased thickness portions **84**A. The lower surface of the tooth **52**A is covered by the bottom plate portion **81**A. Each of the lower side wall portions **83**A is preferably arranged to extend upward from a separate circumferential end portion of the bottom plate portion **81**A. A lower region of each circumferential side surface of the tooth **52**A is preferably covered by a separate one of the lower side wall portions **83**A. Each of the pair of first lower decreased thickness portions **84**A is arranged to extend further upward from an upper end portion of a separate one of the lower side wall portions **83**A. Each first lower decreased thickness portion **84**A is arranged to have a circumferential thickness smaller than that of each lower side wall portion **83**A.

The upper resin member **421**A preferably further includes first upper ribs **65**A. Each first upper rib **65**A is arranged to project in a circumferential direction from a surface of a corresponding one of the first upper decreased thickness portions **64**A toward a corresponding one of the first lower decreased thickness portions **84**A. In addition, the lower resin member **422**A preferably further includes first lower ribs **85**A. Each first lower rib **85**A is arranged to project in the circumferential direction from a surface of a corresponding one of the first lower decreased thickness portions **84**A toward a corresponding one of the first upper decreased thickness portions **64**A. An axial position of each of the first upper decreased thickness portions **64**A and the first upper ribs **65**A is arranged to overlap at least partially with an axial position of each of the first lower decreased thickness portions **84**A and the first lower ribs **85**A.

Each first upper rib **65**A significantly improves the strength of a corresponding one of the first upper decreased thickness portions **64**A. Each first lower rib **85**A significantly improves the strength of a corresponding one of the first lower decreased thickness portions **84**A. This reduces the likelihood that contact between the upper and lower resin members **421**A and **422**A will cause damage of any of the first upper decreased thickness portions **64**A and the first lower decreased thickness portions **84**A when the upper and lower resin members **421**A and **422**A are fitted to each other. In addition, a channel through which a molten resin flows in a molding process is expanded by spaces for molding the ribs **65**A and **85**A. This improves precision with which each of the decreased thickness portions **64**A and **84**A is molded.

Moreover, the first upper ribs **65**A preferably contribute to preventing each first upper decreased thickness portion **64**A from warping because of contraction in the molding process. Similarly, the first lower ribs **85**A preferably contribute to preventing each first lower decreased thickness portion **84**A from warping because of contraction in the molding process. Prevention of warping of each of the first upper decreased thickness portions **64**A and the first lower decreased thickness portions **84**A contributes to preventing contact between each first upper decreased thickness portion **64**A and a corresponding one of the first lower decreased thickness portions **84**A when the upper and lower resin members **421**A and **422**A are fitted to each other.

Note that each of the circumferential thickness of each first upper decreased thickness portion **64**A and the combined circumferential thickness of each first upper decreased thickness portion **64**A and each corresponding first upper rib **65**A may be arranged either to decrease with decreasing height or to be uniform. Also note that each of the circumferential thickness of each first lower decreased thickness portion **84**A and the combined circumferential thickness of each first lower decreased thickness portion **84**A and each corresponding first lower rib **85**A may be arranged either to decrease with increasing height or to be uniform. Also note that the radial width of each first upper rib **65**A may be arranged either to decrease with decreasing height or to be uniform. Also note that the radial width of each first lower rib **85**A may be arranged either to decrease with increasing height or to be uniform.

Second Preferred Embodiment

Next, a second preferred embodiment of the present invention will now be described below.

FIG. **2** is a vertical cross-sectional view of a motor **1** according to a second preferred embodiment of the present invention. The motor **1** according to the second preferred embodiment is preferably, for example, installed in an automobile and used to produce a driving force for a power steering device. Note, however, that motors according to other preferred embodiments of the present invention may be used for applications other than power steering. For example, a motor according to a preferred embodiment of the present invention may be used as a driving source for another portion of the automobile, e.g., an engine cooling fan. Further, motors according to preferred embodiments of the present invention may be installed in household electrical appliances, office automation appliances, medical appliance, and so on, and may be used to produce a variety of driving forces, for example.

Referring to FIG. **2**, the motor **1** includes a stationary portion **2** and a rotating portion **3**. The stationary portion **2** is preferably fixed to a frame of an apparatus which the motor **1** is arranged to drive. The rotating portion **3** is supported to be rotatable with respect to the stationary portion **2**.

The stationary portion **2** according to the present preferred embodiment preferably includes a housing **21**, a cover portion **22**, an armature **23**, a lower bearing portion **24**, and an upper bearing portion **25**.

The housing **21** preferably includes a cylindrical side wall **211** and a bottom portion **212** arranged to close a bottom portion of the side wall **211**. The cover portion **22** is arranged to cover an upper opening of the housing **21**. The armature **23**, a rotor core **32**, which will be described below, and a plurality of magnets **33**, which will be described below, are preferably accommodated in an interior space enclosed by the housing **21** and the cover portion **22**. The housing **21** includes a recessed portion **213** defined in a center of the bottom portion **212**. The recessed portion **213** is preferably arranged to have the lower bearing portion **24** arranged therein. The cover portion **22** includes a circular hole **221** defined in a center thereof. The circular hole **221** is arranged to have the upper bearing portion **25** arranged therein.

The armature **23** preferably includes a stator core **41**, insulators **42**, and coils **43**. The stator core **41** is preferably defined by laminated steel sheets; however, any other desirable type of stator core could be used instead. The laminated steel sheets are preferably a plurality of electromagnetic steel sheets, which are magnetic bodies, placed one upon another in the axial direction, for example. The stator core **41** preferably includes a core back **51** and a plurality of teeth **52**. The core back **51** preferably has an annular shape and is centered on a central axis **9**. An outer circumferential surface of the core back **51** is fixed to an inner circumferential surface of the side wall **211** of the housing **21**. The teeth **52** are preferably arranged to extend radially inward from the core back **51**. In addition, the teeth **52** are arranged at regular intervals in the circumferential direction.

Each insulator **42** preferably includes an upper resin member **421** and a lower resin member **422**. Each of the upper and lower resin members **421** and **422** is made of resin, which is an electrically insulating material. The upper and lower resin members **421** and **422** are preferably attached to each of the teeth **52**. An upper surface, a lower surface, and both circumferential side surfaces of each tooth **52** are covered by the upper and lower resin members **421** and **422**. Each coil **43** is preferably defined by a conducting wire wound around a separate one of the insulators **42**. Each insulator **42** is arranged to intervene between a corresponding one of the teeth **52** and a corresponding one of the coils **43** to ensure more secure insulation between the tooth **52** and the coil **43**.

The lower bearing portion **24** is preferably arranged between the housing **21** and a shaft **31**, which is included in the rotating portion **3**. The upper bearing portion **25** is arranged between the cover portion **22** and the shaft **31**. A ball bearing, in which an outer race and an inner race are caused to rotate relative to each other through a plurality of balls arranged therebetween, is used as each of the lower and upper bearing portions **24** and **25** according to the present preferred embodiment. Note, however, that a bearing of another type, such as, for example, a plain bearing, a fluid bearing, etc. may be used instead of the ball bearing.

An outer race **241** of the lower bearing portion **24** is preferably arranged in the recessed portion **213** of the housing **21** and fixed to the housing **21**. An outer race **251** of the upper bearing portion **25** is preferably arranged in the circular hole **221** of the cover portion **22** and fixed to the cover portion **22**. Meanwhile, inner races **242** and **252** of the lower and upper bearing portions **24** and **25**, respectively, are fixed to the shaft **31**. The shaft **31** is thus supported to be rotatable with respect to the housing **21** and the cover portion **22**.

The rotating portion **3** according to the present preferred embodiment preferably includes the shaft **31**, the rotor core **32**, and the magnets **33**.

The shaft **31** preferably is a columnar metallic member arranged to extend along the central axis **9**. The shaft **31** is arranged to rotate about the central axis **9** while being supported by the above-described lower and upper bearing portions **24** and **25**. The shaft **31** preferably includes a head portion **311** arranged to project upwardly of the cover portion **22**. The head portion **311** is, for example, connected to a steering system of an automobile or the like through a power transmission mechanism, such as, for example, a gear.

The rotor core **32** and the magnets **33** are arranged radially inside the armature **23**, and are arranged to rotate together with the shaft **31**. The rotor core **32** preferably is a cylindrical member fixed to the shaft **31**. The magnets **33** are fixed to an outer circumferential surface of the rotor core **32** through an adhesive, for example. A radially outer surface of each magnet **33** defines a pole surface which is to be opposed to a radially inner end surface of each tooth **52**. The magnets **33** are preferably arranged at regular intervals in the circumferential direction such that north and south pole surfaces alternate with each other.

Note that a single annular magnet including north and south poles arranged to alternate with each other in the circumferential direction may alternatively be used in place of the plurality of magnets **33**, if so desired.

The armature **23** and the magnets **33** are supported to be rotatable relative to each other about the central axis **9**. Once drive currents are supplied to the coils **43** of the armature **23**, radial magnetic flux is generated around each of the teeth **52** of the stator core **41**, and a circumferential torque is produced by interaction between the magnetic flux of the teeth **52** and the magnetic flux of the magnets **33**, so that the rotating portion **3** is caused to rotate about the central axis **9** with respect to the stationary portion **2**.

Next, the detailed structure of the insulator **42** will now be described below. FIG. **3** is a side view of the tooth **52** and the insulator **42** as viewed from a circumferential side. FIG. **4** is an exploded view of the tooth **52** and the upper and lower resin members **421** and **422** as viewed from the circumferential side. FIG. **5** is an exploded view of the tooth **52** and the upper and lower resin members **421** and **422** as viewed from radially inside.

Referring to FIGS. **3** to **5**, a radially inner tip portion **521** of each tooth **52** is arranged to extend radially out beyond both circumferential sides of the tooth **52**. That is, the circumferential width of the tip portion **521** is greater than the circumferential width of a remaining portion of the tooth **52**. A radially inner surface of the tip portion **521** is arranged to be radially opposed to each magnet **33**. As represented by a chain double-dashed line in FIG. **3**, the coil **43** is preferably arranged radially inward of the core back **51** and radially outward of the tip portion **521** of the tooth **52**.

FIG. **6** is a perspective view of the upper resin member **421**. Referring to FIGS. **3** to **6**, the upper resin member **421** preferably includes a first top plate portion **61**, a second top plate portion **62**, a pair of upper side wall portions **63**, a pair of first upper decreased thickness portions **64**, a plurality of first upper ribs **65**, an upper outer wall portion **66**, a pair of second upper decreased thickness portions **67**, a plurality of second upper ribs **68**, a pair of upper inner wall portions **69**, a pair of third upper decreased thickness portions **70**, and a plurality of third upper ribs **71**.

The first top plate portion **61** is arranged above the tooth **52**. The first top plate portion **61** is arranged to join upper end portions of the pair of upper side wall portions **63** to each other in the circumferential direction. The upper surface of the tooth **52** is covered by the first top plate portion **61**. The second top plate portion **62** is arranged above the core back **51**. The second top plate portion **62** is arranged to extend radially outward from an upper end portion of the upper outer wall portion **66**. A portion of an upper surface of the core back **51** is covered by the second top plate portion **62**.

Each of the pair of upper side wall portions **63** is arranged to extend downward from a separate circumferential end portion of the first top plate portion **61**. An upper region of each circumferential side surface of the tooth **52** is covered by a separate one of the upper side wall portions **63**. Each of the pair of first upper decreased thickness portions **64** is arranged to extend further downward from a lower end portion of a separate one of the pair of upper side wall portions **63**. Each first upper decreased thickness portion **64** is arranged to have a circumferential thickness smaller than that of each upper side wall portion **63**. In addition, the circumferential thickness of each first upper decreased thickness portion **64** is arranged to decrease with decreasing height.

Each of the plurality of first upper ribs **65** is arranged to project in the circumferential direction from a surface of a corresponding one of the first upper decreased thickness portions **64** toward a corresponding one of a pair of first lower decreased thickness portions **84**, which will be described below. The first upper ribs **65** are preferably arranged at regular intervals in a radial direction. In addition, each first upper rib **65** is arranged to extend in the axial direction from a location corresponding to an upper end portion of each first upper decreased thickness portion **64** to a location corresponding to a lower end portion of each first upper decreased thickness portion **64**. Each first upper rib **65** significantly improves the rigidity of a corresponding one of the first upper decreased thickness portions **64**. In particular, each first upper rib **65** significantly increases the strength of the corresponding first upper decreased thickness portion **64** against circumferential deformation.

The upper outer wall portion **66** is arranged to extend downward from a radially inner end portion of the second top plate portion **62**. An upper region of a portion of a radially inner surface of the core back **51** is covered by the upper outer wall portion **66**. Each of the pair of second upper decreased thickness portions **67** is arranged to extend further downward from a lower end portion of the upper outer wall portion **66**. Each second upper decreased thickness portion **67** is arranged to have a radial thickness smaller than that of the upper outer wall portion **66**. In addition, the radial thickness of each second upper decreased thickness portion **67** is preferably arranged to decrease with decreasing height.

Each of the plurality of second upper ribs **68** is arranged to project in the radial direction from a surface of a corresponding one of the second upper decreased thickness portions **67** toward a corresponding one of a pair of second lower decreased thickness portions **87**, which will be described below. The second upper ribs **68** are arranged at regular intervals in the circumferential direction. In addition, each second upper rib **68** is arranged to extend in the axial direction from a location corresponding to an upper end portion of each second upper decreased thickness portion **67** to a location corresponding to a lower end portion of each second upper decreased thickness portion **67**. Each second upper rib **68** significantly improves the rigidity of a corresponding one of the second upper decreased thickness portions **67**. In particular, each second upper rib **68** significantly increases strength of the corresponding second upper decreased thickness portion **67** against radial deformation.

Each of the upper inner wall portions **69** is arranged to extend in the circumferential direction from a radially inner end portion of a separate one of the upper side wall portions **63**. An upper region of each of radially outer surfaces of the tip portion **521** of the tooth **52** is covered by a separate one of the upper inner wall portions **69**. Each of the pair of third upper decreased thickness portions **70** is arranged to extend further downward from a lower end portion of a separate one of the upper inner wall portions **69**. Each third upper decreased thickness portion **70** is arranged to have a radial thickness smaller than that of each upper inner wall portion **69**. In addition, the radial thickness of each third upper decreased thickness portion **70** is arranged to decrease with decreasing height.

Each of the plurality of third upper ribs **71** is arranged to project in the radial direction from a surface of a corresponding one of the third upper decreased thickness portions **70** toward a corresponding one of a pair of third lower decreased thickness portions **90**, which will be described below. The third upper ribs **71** are preferably arranged at regular intervals in the circumferential direction. In addition, each third upper rib **71** is arranged to extend in the axial direction from a location corresponding to an upper end portion of each third upper decreased thickness portion **70** to a location corresponding to a lower end portion of each third upper decreased thickness portion **70**. Each third upper rib **71** significantly improves the rigidity of a corresponding one of the third upper decreased thickness portions **70**. In particular, each third upper rib **71** significantly increases the strength of the corresponding third upper decreased thickness portion **70** against radial deformation.

Referring to FIGS. **3** to **5**, the lower resin member **422** preferably includes a first bottom plate portion **81**, a second bottom plate portion **82**, a pair of lower side wall portions **83**, the pair of first lower decreased thickness portions **84**, a plurality of first lower ribs **85**, a lower outer wall portion **86**, the pair of second lower decreased thickness portions **87**, a plurality of second lower ribs **88**, a pair of lower inner wall portions **89**, the pair of third lower decreased thickness portions **90**, and a plurality of third lower ribs **91**.

The first bottom plate portion **81** is arranged below the tooth **52**. The first bottom plate portion **81** is arranged to join lower end portions of the pair of lower side wall portions to each other in the circumferential direction. The lower surface of the tooth **52** is covered by the first bottom plate portion **81**. The second bottom plate portion **82** is arranged below the core back **51**. The second bottom plate portion **82** is arranged to extend radially outward from a lower end portion of the lower outer wall portion **86**. A portion of a lower surface of the core back **51** is covered by the second bottom plate portion **82**.

Each of the pair of lower side wall portions **83** is arranged to extend upward from a separate circumferential end portion of the first bottom plate portion **81**. A lower region of each circumferential side surface of the tooth **52** is covered by a separate one of the lower side wall portions **83**. Each of the pair of first lower decreased thickness portions **84** is arranged to extend further upward from an upper end portion of a separate one of the pair of lower side wall portions **83**. Each first lower decreased thickness portion **84** is arranged to have a circumferential thickness smaller than that of each lower side wall portion **83**. In addition, the circumferential thickness of each first lower decreased thickness portion **84** is preferably arranged to decrease with increasing height.

Each of the plurality of first lower ribs **85** is arranged to project in the circumferential direction from a surface of a corresponding one of the first lower decreased thickness portions **84** toward a corresponding one of the first upper decreased thickness portions **64**. The first lower ribs **85** are arranged at regular intervals in the radial direction. In addition, each first lower rib **85** is arranged to extend in the axial direction from a location corresponding to a lower end portion of each first lower decreased thickness portion **84** to a location corresponding to an upper end portion of each first lower decreased thickness portion **84**. Each first lower rib **85** significantly improves the rigidity of a corresponding one of the first lower decreased thickness portions **84**. In particular, each first lower rib **85** significantly increases the strength of the corresponding first lower decreased thickness portion **84** against circumferential deformation.

The lower outer wall portion **86** is arranged to extend upward from a radially inner end portion of the second bottom plate portion **82**. A lower region of a portion of the radially inner surface of the core back **51** is covered by the lower outer wall portion **86**. Each of the pair of second lower decreased thickness portions **87** is arranged to extend further upward from an upper end portion of the lower outer wall portion **86**. Each second lower decreased thickness portion **87** is arranged to have a radial thickness smaller than that of the lower outer wall portion **86**. In addition, the radial thickness of each second lower decreased thickness portion **87** is arranged to decrease with increasing height.

Each of the plurality of second lower ribs **88** is arranged to project in the radial direction from a surface of a corresponding one of the second lower decreased thickness portions **87** toward a corresponding one of the second upper decreased thickness portions **67**. The second lower ribs **88** are preferably arranged at regular intervals in the circumferential direction. In addition, each second lower rib **88** is arranged to extend in the axial direction from a location corresponding to a lower end portion of each second lower decreased thickness portion **87** to a location corresponding to an upper end portion of each second lower decreased thickness portion **87**. Each second lower rib **88** significantly improves the rigidity of a corresponding one of the second lower decreased thickness portions **87**. In particular, each second lower rib **88** significantly increases the strength of the corresponding second lower decreased thickness portion **87** against radial deformation.

Each of the lower inner wall portions **89** is arranged to extend in the circumferential direction from a radially inner end portion of a separate one of the lower side wall portions **83**. A lower region of each radially outer surface of the tip portion **521** of the tooth **52** is preferably covered by a separate one of the lower inner wall portions **89**. Each of the pair of third lower decreased thickness portions **90** is arranged to extend further upward from an upper end portion of a separate one of the lower inner wall portions **89**. Each third lower decreased thickness portion **90** is arranged to have a radial thickness smaller than that of each lower inner wall portion **89**. In addition, the radial thickness of each third lower decreased thickness portion **90** is arranged to decrease with increasing height.

Each of the plurality of third lower ribs **91** is arranged to project in the radial direction from a surface of a corresponding one of the third lower decreased thickness portions **90** toward a corresponding one of the third upper decreased thickness portions **70**. The third lower ribs **91** are preferably arranged at regular intervals in the circumferential direction. In addition, each third lower rib **91** is arranged to extend in the axial direction from a location corresponding to a lower end portion of each third lower decreased thickness portion **90** to a location corresponding to an upper end portion of each third lower decreased thickness portion **90**. Each third lower rib **91** significantly improves the rigidity of a corresponding one of the third lower decreased thickness portions **90**. In particular, each third lower rib **91** significantly increases the strength of the corresponding third lower decreased thickness portion **90** against radial deformation.

The axial position of each of the pair of first upper decreased thickness portions **64** and the plurality of first upper ribs **65** is arranged to overlap at least partially with the axial position of each of the pair of first lower decreased thickness portions **84** and the plurality of first lower ribs **85**. This arrangement prevents contact between each circumferential side surface of the tooth **52** and the coil **43**. In addition, the axial position of each of the pair of second upper decreased thickness portions **67** and the plurality of second upper ribs **68** is arranged to overlap at least partially with the axial position of each of the pair of second lower decreased thickness portions and the plurality of second lower ribs **88**. This prevents contact between the core back **51** and the coil **43**.

In addition, the axial position of each of the pair of third upper decreased thickness portions **70** and the plurality of third upper ribs **71** is arranged to overlap at least partially with the axial position of each of the pair of third lower decreased thickness portions **90** and the plurality of third lower ribs **91**. This prevents contact between the tip portion **521** of the tooth **52** and the coil **43**. Electrical insulation between the stator core **41** and the coil **43** is thereby ensured.

As described above, the rigidity of the first, second, and third upper decreased thickness portions **64**, **67**, and **70** is increased by the first, second, and third upper ribs **65**, **68**, and **71**, respectively. In addition, the rigidity of the first, second, and third lower decreased thickness portions **84**, **87**, and **90** is increased by the first, second, and third lower ribs **85**, **88**, and **91**, respectively. This reduces the likelihood that contact between the upper and lower resin members **421** and **422** will cause damage to any of the first, second, and third upper decreased thickness portions **64**, **67**, and **70** and the first, second, and third lower decreased thickness portions **84**, **87**, and **90** when the upper and lower resin members **421** and **422** are fitted to each other.

Each of the upper and lower resin members **421** and **422** is preferably obtained by, for example, a resin injection molding process. Channels through which a molten resin flows in the injection molding process are expanded by spaces used in molding the first, second, and third upper ribs **65**, **68**, and **71** and spaces used in molding the first, second, and third lower ribs **85**, **88**, and **91**. This improves precision with which each of the first, second, and third upper decreased thickness portions **64**, **67**, and **70** and the first, second, and third lower decreased thickness portions **84**, **87**, and **90** is molded.

In addition, the first, second, and third upper ribs **65**, **68**, and **71** and the first, second, and third lower ribs **85**, **88**, and **91** contribute to preventing the first, second, and third upper decreased thickness portions **64**, **67**, and **70** and the first, second, and third lower decreased thickness portions **84**, **87**, and **90**, respectively, from warping because of contraction in the injection molding process. Prevention of warping of each of the first, second, and third upper decreased thickness portions **64**, **67**, and **70** and the first, second, and third lower decreased thickness portions **84**, **87**, and **90** preferably contributes to preventing contact between the first upper decreased thickness portions **64** and the first lower decreased thickness portions **84**, contact between the second upper decreased thickness portions **67** and the second lower decreased thickness portions **87**, and contact between the third upper decreased thickness portions **70** and the third lower decreased thickness portions **90** when the upper and lower resin members **421** and **422** are fitted to each other.

Moreover, the first upper ribs **65** and the first lower ribs **85** of the insulator **42** are not circumferentially opposed to each other. Each first upper rib **65** is circumferentially opposed to a corresponding one of the first lower decreased thickness portions **84**. Meanwhile, each first lower rib **85** is circumferentially opposed to a corresponding one of the first upper decreased thickness portions **64**. The circumferential position of each of the plurality of first upper ribs **65** and the circumferential position of each of the plurality of first lower ribs **85** are arranged to overlap with each other. That is, the first upper ribs **65** and the first lower ribs **85** are arranged radially adjacent to each other. This leads to a reduction in the overall circumferential thickness of each first upper decreased thickness portion **64**, each corresponding first upper rib **65**, the corresponding first lower decreased thickness portion **84**, and each corresponding first lower rib **85**. A wider space is thereby secured for the coil **43**.

Furthermore, the second upper ribs **68** and the second lower ribs **88** of the insulator **42** are not radially opposed to each other. Each second upper rib **68** is radially opposed to a corresponding one of the second lower decreased thickness portions **87**. Meanwhile, each second lower rib **88** is radially opposed to a corresponding one of the second upper decreased thickness portions **67**. The radial position of each of the plurality of second upper ribs **68** and the radial position of each of the plurality of second lower ribs **88** are arranged to overlap with each other. That is, the second upper ribs **68** and the second lower ribs **88** are arranged circumferentially adjacent to each other. This leads to a reduction in the overall radial thickness of each second upper decreased thickness portion **67**, each corresponding second upper rib **68**, the corresponding second lower decreased thickness portion **87**, and each corresponding second lower rib **88**. A still wider space is thereby preferably secured for the coil **43**.

Furthermore, the third upper ribs **71** and the third lower ribs **91** of the insulator **42** are not radially opposed to each other. Each third upper rib **71** is radially opposed to a corresponding one of the third lower decreased thickness portions **90**. Meanwhile, each third lower rib **91** is radially opposed to a corresponding one of the third upper decreased thickness portions **70**. The radial position of each of the plurality of third upper ribs **71** and the radial position of each of the plurality of third lower ribs **91** are preferably arranged to overlap with each other. That is, the third upper ribs **71** and the third lower ribs **91** are arranged circumferentially adjacent to each other. This leads to a reduction in the overall radial thickness of each third upper decreased thickness portion **70**, each corresponding third upper rib **71**, the corresponding third lower decreased thickness portion **90**, and each corresponding third lower rib **91**. A still wider space is thereby secured for the coil **43**.

Each of the number of first upper ribs **65**, the number of second upper ribs **68**, and the number of third upper ribs **71** included in the upper resin member **421** according to the present preferred embodiment is preferably more than one. This contributes to reducing unevenness in the strength of each of the first, second, and third upper decreased thickness portions **64**, **67**, and **70**. Moreover, the channel through which the molten resin flows in the molding process is preferably further expanded by the plurality of each of the first upper ribs **65**, the second upper ribs **68**, and the third upper ribs **71**. This improves the precision with which each of the first, second, and third upper decreased thickness portions **64**, **67**, and **70** is molded.

Each of the number of first lower ribs **85**, the number of second lower ribs **88**, and the number of third lower ribs **91** inclined in the lower resin member **422** according to the present preferred embodiment is preferably more than one. This contributes to reducing unevenness in the strength of each of the first, second, and third lower decreased thickness portions **84**, **87**, and **90**. Moreover, the channel through which the molten resin flows in the molding process is further expanded by the plurality of each of the first lower ribs **85**, the second lower ribs **88**, and the third lower ribs **91**. This improves the precision with which each of the first, second, and third lower decreased thickness portions **84**, **87**, and **90** is molded.

Referring to FIG. **4**, the radial interval d**1** between adjacent ones of the plurality of first upper ribs **65** is preferably arranged to be greater than the radial dimension d**2** of each individual first lower rib **85**. In addition, the radial interval d**3** between adjacent ones of the plurality of first lower ribs **85** is preferably arranged to be greater than the radial dimension d**4** of each individual first upper rib **65**. Similarly, the circumferential interval between adjacent ones of the plurality of second upper ribs **68** is arranged to be greater than the circumferential dimension of each individual second lower rib **88**. In addition, the circumferential interval between adjacent ones of the plurality of second lower ribs **88** is preferably arranged to be greater than the circumferential dimension of each individual second upper rib **68**. Similarly, the circumferential interval between adjacent ones of the third upper ribs **71** is preferably arranged to be greater than the circumferential dimension of each individual third lower rib **91**. In addition, the circumferential interval between adjacent ones of the third lower ribs **91** is arranged to be greater than the circumferential dimension of each individual third upper rib **71**. It is therefore possible to fit the upper and lower resin members **421** and **422** to each other without interference therebetween.

Each rib projecting from one of each first upper decreased thickness portion **64** and the corresponding first lower decreased thickness portion **84** which is closer to the coil **43** is preferably arranged to have a radial width greater than that of each rib projecting from the other decreased thickness portion. In the case of FIG. **4**, for example, the dimension d2 is preferably arranged to be greater than the dimension d**4**. This reduces the likelihood that the decreased thickness portion that is closer to the coil **43** will tilt toward the tooth **52**. This contributes to more securely preventing contact between the first upper decreased thickness portion **64** and the first lower decreased thickness portion **84**.

Similarly, each rib projecting from one of each second upper decreased thickness portion **67** and the corresponding second lower decreased thickness portion **87** which is closer to the coil **43** is preferably arranged to have a circumferential width greater than that of each rib projecting from the other decreased thickness portion. Moreover, each rib projecting from one of each third upper decreased thickness portion **70** and the corresponding third lower decreased thickness portion **90** which is closer to the coil **43** is preferably arranged to have a circumferential width greater than that of each rib projecting from the other decreased thickness portion.

FIG. **7** is a partial perspective view of the stator core **41** and the insulator **42**. In FIG. **7**, each of the tooth **52** and the insulator **42** is cut away. FIG. **8** is a cross-sectional view of the tooth **52** and the insulator **42** taken along a plane perpendicular to a direction in which the tooth **52** extends. Both a cut-out section of FIG. **7** and a vertical section of FIG. **8** are taken along line A-A in FIG. **3**. FIG. **8** also illustrates an area including one of the first upper decreased thickness portions **64**, one of the first upper ribs **65**, one of the first lower decreased thickness portions **84**, and one of the first lower ribs **85**, and its vicinity in an enlarged form.

Referring to FIGS. **7** and **8**, in the present preferred embodiment, one of the pair of first lower decreased thickness portions **84** arranged on both circumferential sides of the tooth **52** is arranged between the tooth **52** and one of the pair of first upper decreased thickness portions **64** arranged on both circumferential sides of the tooth **52**. In addition, the other one of the pair of first upper decreased thickness portions **64** arranged on both circumferential sides of the tooth **52** is arranged between the tooth **52** and the other one of the first lower decreased thickness portions **84** arranged on both circumferential sides of the tooth **52**.

This enables each of the upper and lower resin members **421** and **422** to have the same shape. This in turn makes it possible to preferably mold each of the upper and lower resin members **421** and **422** using the same mold, for example. This makes it possible to produce the upper and lower resin members **421** and **422** at a lower cost and efficiently. Moreover, one of the two decreased thickness portions of each resin member is spaced from the tooth **52**. This enables each resin member to be fitted to the tooth **52** with greater ease.

Each of the decreased thickness portions and the ribs is preferably arranged to have a shape so as to facilitate a mold release from the mold in the injection molding process. For example, each of the circumferential thickness of each first upper decreased thickness portion **64** and the combined circumferential thickness of each first upper decreased thickness portion **64** and each corresponding first upper rib **65** is preferably arranged to decrease with decreasing height or to be uniform. Moreover, the radial width of each first upper rib **65** is preferably arranged to decrease with decreasing height or to be uniform.

Similarly, each of the radial thickness of each second upper decreased thickness portion **67** and the combined radial thickness of each second upper decreased thickness portion **67** and each corresponding second upper rib **68** is preferably arranged to decrease with decreasing height or to be uniform. Moreover, each of the radial thickness of each third upper decreased thickness portion **70** and the combined radial thickness of each third upper decreased thickness portion **70** and each corresponding third upper rib **71** is preferably arranged to decrease with decreasing height or to be uniform. Furthermore, the circumferential width of each of the second and third upper ribs **68** and **71** is preferably arranged to decrease with decreasing height or to be uniform.

Meanwhile, each of the circumferential thickness of each first lower decreased thickness portion **84** and the combined circumferential thickness of each first lower decreased thickness portion **84** and each corresponding first lower rib **85** is preferably arranged to decrease with increasing height or to be uniform. Moreover, the radial width of each first lower rib **85** is preferably arranged to decrease with increasing height or to be uniform.

Moreover, each of the radial thickness of each second lower decreased thickness portion **87** and the combined radial thickness of each second lower decreased thickness portion **87** and each corresponding second lower rib **88** is preferably arranged to decrease with increasing height or to be uniform. Furthermore, each of the radial thickness of each third lower decreased thickness portion **90** and the combined radial thickness of each third lower decreased thickness portion **90** and each corresponding third lower rib **91** is preferably arranged to decrease with increasing height or to be uniform. Furthermore, the circumferential width of each of the second and third lower ribs **88** and **91** is preferably arranged to decrease with increasing height or to be uniform.

According to the present preferred embodiment, the thickness of each decreased thickness portion is arranged to gradually decrease toward a tip thereof. Moreover, the combined thickness of each decreased thickness portion and each corresponding rib is also arranged to gradually decrease toward tips thereof. In addition, each upper decreased thickness portion and each corresponding upper rib, and the corresponding lower decreased thickness portion and each corresponding lower rib, are arranged to have mutually opposing inclined surfaces. The above arrangements make it easier for the upper and lower resin members **421** and **422** to be fitted to each other.

In the armature **23**, the upper surface of the tooth **52** and a lower surface of the first top plate portion **61** of the upper resin member **421** are preferably arranged to be in contact with each other. Accordingly, the axial position of the upper resin member **421** with respect to the tooth **52** is determined based on a position of contact between the first top plate portion **61** and the upper surface of the tooth **52**. Meanwhile, the lower surface of the tooth **52** and an upper surface of the first bottom plate portion **81** of the lower resin member **422** are preferably arranged to be in contact with each other. Accordingly, the axial position of the lower resin member **422** with respect to the tooth **52** is determined based on a position of contact between the first bottom plate portion **81** and the lower surface of the tooth **52**.

In addition, referring to the enlarged drawing of FIG. **8**, a lower end of each of each first upper decreased thickness portion **64** and each corresponding first upper rib **65** is axially opposed to an upper end of a corresponding one of the lower side wall portions **83** with a gap intervening therebetween. Moreover, an upper end of each of each first lower decreased thickness portion **84** and each corresponding first lower rib **85** is axially opposed to a lower end of a corresponding one of the upper side wall portions **63** with a gap intervening therebetween. Similarly, a lower end of each of each second upper decreased thickness portion **67** and each corresponding second upper rib **68** is axially opposed to an upper end of the lower outer wall portion **86** with a gap intervening therebetween. Moreover, an upper end of each of each second lower decreased thickness portion **87** and each corresponding second lower rib **88** is axially opposed to a lower end of the upper outer wall portion **66** with a gap intervening therebetween. Similarly, a lower end of each of each third upper decreased thickness portion **70** and each corresponding third upper rib **71** is axially opposed to an upper end of a corresponding one of the lower inner wall portions **89** with a gap intervening therebetween. Moreover, an upper end of each of each third lower decreased thickness portion **90** and each corresponding third lower rib **91** is axially opposed to a lower end of a corresponding one of the upper inner wall portions **69** with a gap intervening therebetween.

Accordingly, any variation in the axial dimension of any of the tooth **52** and the upper and lower resin members **421** and **422** will not easily result in contact between the upper and lower resin members **421** and **422**. In particular, the stator core **41**, which is defined by laminated steel sheets, tends to easily suffer errors in the axial dimension. According to the present preferred embodiment, however, a problematic arrangement of the upper and lower resin members **421** and **422** will not easily occur.

In addition, referring to the enlarged drawing of FIG. **8**, each first upper rib **65** and a corresponding one of the first lower decreased thickness portions **84** according to the present preferred embodiment are arranged to have a pair of opposed surfaces parallel or substantially parallel to each other. This arrangement enables the first upper rib **65** to be arranged widely along a surface of the corresponding first lower decreased thickness portion **84**. This contributes to further increasing the rigidity of each first upper decreased thickness portion **64**. Similarly, each first lower rib **85** and a corresponding one of the first upper decreased thickness portions **64** are arranged to have a pair of opposed surfaces parallel or substantially parallel to each other. This arrangement enables the first lower rib **85** to be arranged widely along a surface of the corresponding first upper decreased thickness portion **64**. This contributes to further increasing the rigidity of each first lower decreased thickness portion **84**.

Similarly, each second upper rib **68** and a corresponding one of the second lower decreased thickness portions **87** according to the present preferred embodiment are arranged to have a pair of opposed surfaces parallel or substantially parallel to each other. In addition, each second lower rib **88** and a corresponding one of the second upper decreased thickness portions **67** are arranged to have a pair of opposed surfaces parallel or substantially parallel to each other. Moreover, each third upper rib **71** and a corresponding one of the third lower decreased thickness portions **90** are arranged to have a pair of opposed surfaces parallel to each other. Furthermore, each third lower rib **91** and a corresponding one of the third upper decreased thickness portions **70** are arranged to have a pair of opposed surfaces parallel or substantially parallel to each other.

In addition, referring to the enlarged drawing of FIG. **8**, each first upper rib **65** according to the present preferred embodiment preferably includes an upper tapered surface **651** defined at a lower end portion of the surface opposed to the corresponding first lower decreased thickness portion **84**. The distance between the upper tapered surface **651** and the corresponding first lower decreased thickness portion **84** is arranged to increase with decreasing height. Moreover, each first lower rib **85** according to the present preferred embodiment preferably includes a lower tapered surface **851** defined at an upper end portion of the surface opposed to the corresponding first upper decreased thickness portion **64**. The distance between the lower tapered surface **851** and the corresponding first upper decreased thickness portion **64** is arranged to increase with increasing height. Fitting of the upper and lower resin members **421** and **422** to each other is facilitated by the upper and lower tapered surfaces **651** and **851**.

Each of the second upper ribs **68**, the second lower ribs **88**, the third upper ribs **71**, and the third lower ribs **91** also preferably includes a similar tapered surface.

In addition, referring to the enlarged drawing of FIG. **8**, the upper resin member **421** according to the present preferred embodiment preferably includes a shoulder surface **72** defined between each upper side wall portion **63** and a corresponding one of the first upper decreased thickness portions **64**. In addition, the upper resin member **421** according to the present preferred embodiment preferably further includes a shoulder surface **73** defined between each upper side wall portion **63** and each corresponding first upper rib **65**. The circumferential width of a portion of the upper resin member **421** varies at each of the shoulder surfaces **72** and **73**. This contributes to reducing the axial dimension of each of the first upper decreased thickness portions **64** and the first upper ribs **65** while increasing the axial dimension of each upper side wall portion **63**. This contributes to further increasing the strength of the upper resin member **421**.

Note that the upper resin member **421** may include inclined surfaces in place of the shoulder surfaces **72** and **73**. In this case, the inclination of each inclined surface with respect to a horizontal plane is arranged to be smaller than the inclination of a surface of each of the first upper decreased thickness portions **64** and the first upper ribs **65**, the surface facing the corresponding first lower decreased thickness portion **84**, with respect to the horizontal plane.

Moreover, the lower resin member **422** according to the present preferred embodiment preferably includes a shoulder surface **92** defined between each lower side wall portion **83** and a corresponding one of the first lower decreased thickness portions **84**. In addition, the lower resin member **422** according to the present preferred embodiment further includes a shoulder surface **93** defined between each lower side wall portion **83** and each corresponding first lower rib **85**. The circumferential width of a portion of the lower resin member **422** varies at each of the shoulder surfaces **92** and **93**. This contributes to reducing the axial dimension of each of the first lower decreased thickness portions **84** and the first lower ribs **85** while increasing the axial dimension of each lower side wall portion **83**. This contributes to further increasing the strength of the lower resin member **422**.

Note that the lower resin member **422** may include inclined surfaces in place of the shoulder surfaces **92** and **93**. In this case, the inclination of each inclined surface with respect to the horizontal plane is arranged to be smaller than the inclination of a surface of each of the first lower decreased thickness portions **84** and the first lower ribs **85**, the surface facing the corresponding first upper decreased thickness portion **64**, with respect to the horizontal plane.

Furthermore, similar shoulder surfaces or inclined surfaces are preferably defined between the upper outer wall portion **66** and each second upper decreased thickness portion **67**, between each upper inner wall portion **69** and a corresponding one of the third upper decreased thickness portions **70**, between the lower outer wall portion **86** and each second lower decreased thickness portion **87**, and between each lower inner wall portion **89** and a corresponding one of the third lower decreased thickness portions **90**.

Furthermore, the upper resin member **421** according to the present preferred embodiment preferably includes a curved surface **74** defined between an upper surface of the first top plate portion **61** and a surface of each upper side wall portion **63** which faces the coil **43**. In addition, the lower resin member **422** according to the present preferred embodiment preferably includes a curved surface **94** defined between a lower surface of the first bottom plate portion **81** and a surface of each lower side wall portion **83** which faces the coil **43**. Each of these curved surfaces **74** and **94** is preferably arranged to have a radius of curvature that is about twice or more than twice the diameter of the conducting wire defining the coil **43**, for example. This arrangement contributes to preventing the coil **43** from bulging in a direction away from the tooth **52** on each circumferential side of the tooth **52**, and thereby bringing the coil **43** closer to each of the first upper decreased thickness portions **64** and the first lower decreased thickness portions **84**. This contributes to further expanding the space in which the coil **43** is arranged. Note that each of the curved surfaces **74** and **94** is more preferably arranged to have a radius of curvature that is about three or more times the diameter of the conducting wire defining the coil **43**, for example.

Other Preferred Embodiments

While preferred embodiments of the present invention have been described above, it is to be understood that the present invention is not limited to the above-described preferred embodiments.

FIG. **9** is a partial vertical cross-sectional view of an upper resin member **421**B and a lower resin member **422**B according to a modification of a preferred embodiment of the present invention. In the modification of a preferred embodiment of the present invention illustrated in FIG. **9**, a first upper rib **65**B is arranged to extend from an axial position midway through a first upper decreased thickness portion **64**B to a location corresponding to a lower end portion of the first upper decreased thickness portion **64**B. In addition, a first lower rib **85**B is arranged to extend from an axial position midway through a first lower decreased thickness portion **84**B to a level of an upper end portion of the first lower decreased thickness portion **84**B. Each rib may thus be arranged to extend over only a portion of the axial length of a corresponding one of the decreased thickness portions.

FIG. **10** is a partial exploded perspective view of an upper resin member **421**C and a lower resin member **422**C according to another modification of a preferred embodiment of the present invention. In the modification of a preferred embodiment of the present invention illustrated in FIG. **10**, triangular ribs **75**C and a quadrilateral rib **76**C are arranged alternately in the radial direction on a surface of a first upper decreased thickness portion **64**C which is to face a first lower decreased thickness portion **84**C. The circumferential thickness of each triangular rib **75**C is arranged to decrease with decreasing height. The circumferential thickness of the quadrilateral rib **76**C is arranged to be uniform throughout an entire axial length of the quadrilateral rib **76**C. Similar triangular ribs and a similar quadrilateral rib are arranged in the lower resin member **422**C.

An upper portion of each triangular rib **75**C is preferably arranged to project above an upper portion of the quadrilateral rib **76**C toward the first lower decreased thickness portion **84**C. A lower portion of the quadrilateral rib **76**C is arranged to project above a lower portion of each triangular rib **75**C toward the first lower decreased thickness portion **84**C. As described above, two types of ribs may be arranged on each decreased thickness portion. Note that a triangular rib whose surface has an angle of inclination different from that of each triangular rib **75**C may be provided in place of the quadrilateral rib **76**C.

In the modification of a preferred embodiment of the present invention illustrated in FIG. **9**, the first upper rib **65**B and the first lower rib **85**B are circumferentially opposed to each other. In the modification of a preferred embodiment of the present invention illustrated in FIG. **10**, the triangular ribs of the upper and lower resin members are circumferentially opposed to each other, and the quadrilateral ribs of the upper and lower resin members are circumferentially opposed to each other. As described above, the ribs of the upper and lower resin members may be opposed to each other.

Note that the shape of each member need not necessarily be the same shape as illustrated in the accompanying drawings of the present application. For example, the number of ribs arranged on each decreased thickness portion may be different from the number illustrated in the accompanying drawings of the present application. Also note that the insulator may not necessarily include all of the upper outer wall portion, the second upper decreased thickness portions, the second upper ribs, the upper inner wall portions, the third upper decreased thickness portions, the third upper ribs, the lower outer wall portion, the second lower decreased thickness portions, the second lower ribs, the lower inner wall portions, the third lower decreased thickness portions, and the third lower ribs.

Note that the stator core may be defined either by a single member or by a plurality of members combined together. Also note that the armature may be arranged either radially inward of the magnet(s) or radially outward of the magnet(s). That is, the plurality of teeth of the stator core may be arranged to extend either radially inward or radially outward from the annular core back.

Also note that features of the above-described preferred embodiments and the modifications thereof may be combined appropriately as long as no conflict arises.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

**1**. An armature comprising:

a core back;

a plurality of teeth arranged to extend radially inward or radially outward from the core back;

insulators, each of which is arranged to cover a separate one of the teeth; and coils, each of which is defined by a conducting wire wound around a separate one of the insulators; wherein

each insulator includes an upper resin member and a lower resin member;

the upper resin member includes:

a top plate portion arranged to cover an upper surface of a corresponding one of the teeth;

a pair of upper side wall portions, each of which is arranged to extend downward from a separate circumferential end portion of the top plate portion to cover an upper region of a separate one of circumferential side surfaces of the tooth;

a pair of first upper decreased thickness portions, each of which is arranged to extend further downward from a lower end portion of a separate one of the upper side wall portions, each of the pair of first upper decreased thickness portions having a circumferential thickness smaller than that of each upper side wall portion; and

a first upper rib;

the lower resin member includes:

a bottom plate portion arranged to cover a lower surface of the tooth;

a pair of lower side wall portions, each of which is arranged to extend upward from a separate circumferential end portion of the bottom plate portion to cover a lower region of a separate one of the circumferential side surfaces of the tooth;

a pair of first lower decreased thickness portions, each of which is arranged to extend further upward from an upper end portion of a separate one of the lower side wall portions, each of the pair of first lower decreased thickness portions having a circumferential thickness smaller than that of each lower side wall portion; and

a first lower rib;

an axial position of each of the first upper decreased thickness portions and the first upper rib is arranged to overlap at least partially with an axial position of each of the first lower decreased thickness portions and the first lower rib;

the first upper rib is arranged to project in a circumferential direction from a surface of a corresponding one of the first upper decreased thickness portions toward a corresponding one of the first lower decreased thickness portions;

the first lower rib is arranged to project in the circumferential direction from a surface of a corresponding one of the first lower decreased thickness portions toward a corresponding one of the first upper decreased thickness portions;

each of the circumferential thickness of each first upper decreased thickness portion and a combined circumferential thickness of the first upper decreased thickness portion and the first upper rib is arranged to decrease with decreasing height or to be uniform;

each of the circumferential thickness of each first lower decreased thickness portion and a combined circumferential thickness of the first lower decreased thickness portion and the first lower rib is arranged to decrease with increasing height or to be uniform;

a radial width of the first upper rib is arranged to decrease with decreasing height or to be uniform; and

a radial width of the first lower rib is arranged to decrease with increasing height or to be uniform.

**2**. The armature according to claim **1**, wherein

the first upper rib and the corresponding first lower decreased thickness portion are circumferentially opposed to each other;

the first lower rib and the corresponding first upper decreased thickness portion are circumferentially opposed to each other; and

the first upper rib and the first lower rib are arranged radially adjacent to each other.

**3**. The armature according to claim **1**, wherein

the upper surface of the tooth and a lower surface of the top plate portion are arranged to be in contact with each other; and

the lower surface of the tooth and an upper surface of the bottom plate portion are arranged to be in contact with each other.

**4**. The armature according to claim **3**, wherein

a lower end of each of the first upper rib and the first upper decreased thickness portions is axially opposed to an upper end of a corresponding one of the lower side wall portions with a gap intervening therebetween; and

an upper end of each of the first lower rib and the first lower decreased thickness portions is axially opposed to a lower end of a corresponding one of the upper side wall portions with a gap intervening therebetween.

**5**. The armature according to claim **1**, wherein

a total number of first upper ribs included in the upper resin member is more than one; and

a total number of first lower ribs included in the lower resin member is more than one.

**6**. The armature according to claim **5**, wherein

the upper surface of the tooth and a lower surface of the top plate portion are arranged to be in contact with each other;

the lower surface of the tooth and an upper surface of the bottom plate portion are arranged to be in contact with each other;

a radial interval between adjacent ones of the first upper ribs is arranged to be greater than a radial dimension of each individual first lower rib; and

a radial interval between adjacent ones of the first lower ribs is arranged to be greater than a radial dimension of each individual first upper rib.

**7**. The armature according to claim **1**, wherein

one of the pair of first lower decreased thickness portions arranged on both circumferential sides of the tooth is arranged between the tooth and one of the pair of first upper decreased thickness portions arranged on both circumferential sides of the tooth; and

another one of the pair of first upper decreased thickness portions arranged on both circumferential sides of the tooth is arranged between the tooth and the another one of the pair of first lower decreased thickness portions arranged on both circumferential sides of the tooth.

**8**. The armature according to claim **6**, wherein

one of the pair of first lower decreased thickness portions arranged on both circumferential sides of the tooth is arranged between the tooth and one of the pair of first upper decreased thickness portions arranged on both circumferential sides of the tooth; and

another one of the pair of first upper decreased thickness portions arranged on both circumferential sides of the tooth is arranged between the tooth and the another one of the pair of first lower decreased thickness portions arranged on both circumferential sides of the tooth.

**9**. The armature according to claim **1**, wherein

the first upper rib and the corresponding first lower decreased thickness portion include a pair of opposed surfaces parallel or substantially parallel to each other; and the first lower rib and the corresponding first upper decreased thickness portion include a pair of opposed surfaces parallel or substantially parallel to each other.

**10**. The armature according to claim **1**, wherein

the first upper rib includes an upper tapered surface provided at a lower end portion of a surface thereof opposed to the corresponding first lower decreased thickness portion, the upper tapered surface becoming progressively more distant from the corresponding first lower decreased thickness portion with decreasing height; and

the first lower rib includes a lower tapered surface provided at an upper end portion of a surface thereof opposed to the corresponding first upper decreased thickness portion, the lower tapered surface becoming progressively more distant from the corresponding first upper decreased thickness portion with increasing height.

**11**. The armature according to claim **1**, wherein a radial width of the rib projecting from one of the first upper decreased thickness portion and the first lower decreased thickness portion which is closer to a corresponding one of the coils is arranged to be greater than a radial width of the rib projecting from the other one of the first upper decreased thickness portion and the first lower decreased thickness portion.

**12**. The armature according to claim **1**, wherein

the upper resin member includes a curved surface defined between an upper surface of the top plate portion and a surface of each upper side wall portion which faces a corresponding one of the coils, the curved surface having a radius of curvature twice or more than twice a diameter of the conducting wire; and

the lower resin member includes a curved surface defined between a lower surface of the bottom plate portion and a surface of each lower side wall portion which faces the corresponding coil, the curved surface having a radius of curvature twice or more than twice the diameter of the conducting wire.

**13**. The armature according to claim **8**, wherein

the upper resin member further includes an inclined surface or a shoulder surface defined between each upper side wall portion and a corresponding one of the first upper decreased thickness portions, the inclined surface having a smaller inclination with respect to a horizontal plane than that of a surface of the corresponding first upper decreased thickness portion which faces a corresponding one of the first lower decreased thickness portions; and

the lower resin member further includes an inclined surface or a shoulder surface defined between each lower side wall portion and a corresponding one of the first lower decreased thickness portions, the inclined surface having a smaller inclination with respect to the horizontal plane than that of a surface of the corresponding first lower decreased thickness portion which faces a corresponding one of the first upper decreased thickness portions.

**14**. The armature according to claim **8**, wherein

the upper resin member further includes an inclined surface or a shoulder surface defined between each upper side wall portion and each corresponding one of the first upper ribs, the inclined surface having a smaller inclination with respect to a horizontal plane than that of a surface of the corresponding first upper rib which faces a corresponding one of the first lower decreased thickness portions; and

the lower resin member further includes an inclined surface or a shoulder surface defined between each lower side wall portion and each corresponding one of the first lower ribs, the inclined surface having a smaller inclination with respect to the horizontal plane than that of a surface of the corresponding first lower rib which faces a corresponding one of the first upper decreased thickness portions.

**15**. The armature according to claim **8**, wherein

each first upper rib is arranged to extend in an axial direction from a location corresponding to an upper end portion of each first upper decreased thickness portion to a location corresponding to a lower end portion of the first upper decreased thickness portion; and

each first lower rib is arranged to extend in the axial direction from a location corresponding to a lower end portion of each first lower decreased thickness portion to a location corresponding to of an upper end portion of the first lower decreased thickness portion.

**16**. The armature according to claim **8**, wherein the upper resin member further includes:

an upper outer wall portion arranged to cover an upper region of a surface of the core back which faces a corresponding one of the coils;

a pair of second upper decreased thickness portions each of which is arranged to extend further downward from a lower end portion of the upper outer wall portion, each second upper decreased thickness portion having a radial thickness smaller than a radial thickness of the upper outer wall portion; and

a second upper rib arranged to project in a radial direction from a surface of a corresponding one of the second upper decreased thickness portions;

the lower resin member further includes:

a lower outer wall portion arranged to cover a lower region of the surface of the core back which faces the corresponding coil;

a pair of second lower decreased thickness portions each of which is arranged to extend further upward from an upper end portion of the lower outer wall portion, each second lower decreased thickness portion having a radial thickness smaller than a radial thickness of the lower outer wall portion; and

a second lower rib arranged to project in the radial direction from a surface of a corresponding one of the second lower decreased thickness portions;

an axial position of each of the second upper decreased thickness portions and the second upper rib is arranged to overlap at least partially with an axial position of each of the second lower decreased thickness portions and the second lower rib;

the second upper rib and a corresponding one of the second lower decreased thickness portions are radially opposed to each other; and

the second lower rib and a corresponding one of the second upper decreased thickness portions are radially opposed to each other.

**17**. The armature according to claim **8**, wherein each of the teeth includes a tip portion arranged to extend out in the circumferential direction;

the upper resin member further includes:

a pair of upper inner wall portions, each of which is arranged to cover an upper region of a surface of the tip portion which faces a corresponding one of the coils;

a pair of third upper decreased thickness portions, each of which is arranged to extend further downward from a lower end portion of a separate one of the upper inner wall portions, each third upper decreased thickness portion having a radial thickness smaller than that of each upper inner wall portion; and

a third upper rib arranged to project in a radial direction from a surface of a corresponding one of the third upper decreased thickness portions;

the lower resin member further includes:

a pair of lower inner wall portions each of which is arranged to cover a lower region of the surface of the tip portion which faces the corresponding coil;

a pair of third lower decreased thickness portions each of which is arranged to extend further upward from an upper end portion of a separate one of the lower inner wall portions, each third lower decreased thickness portion having a radial thickness smaller than that of each lower inner wall portion; and

a third lower rib arranged to project in the radial direction from a surface of a corresponding one of the third lower decreased thickness portions;

an axial position of each of the third upper decreased thickness portions and the third upper rib is arranged to overlap at least partially with an axial position of each of the third lower decreased thickness portions and the third lower rib;

the third upper rib and a corresponding one of the third lower decreased thickness portions are radially opposed to each other; and

the third lower rib and a corresponding one of the third upper decreased thickness portions are radially opposed to each other.

**18**. A motor comprising:

the armature of claim **1**; and

a magnet including a pole surface opposed to an end surface of each of the plurality of teeth; wherein

the armature and the magnet are supported to be rotatable relative to each other about a central axis.

**19**. A motor comprising:

the armature of claim **8**; and

a magnet including a pole surface opposed to an end surface of each of the plurality of teeth; wherein

the armature and the magnet are supported to be rotatable relative to each other about a central axis.

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